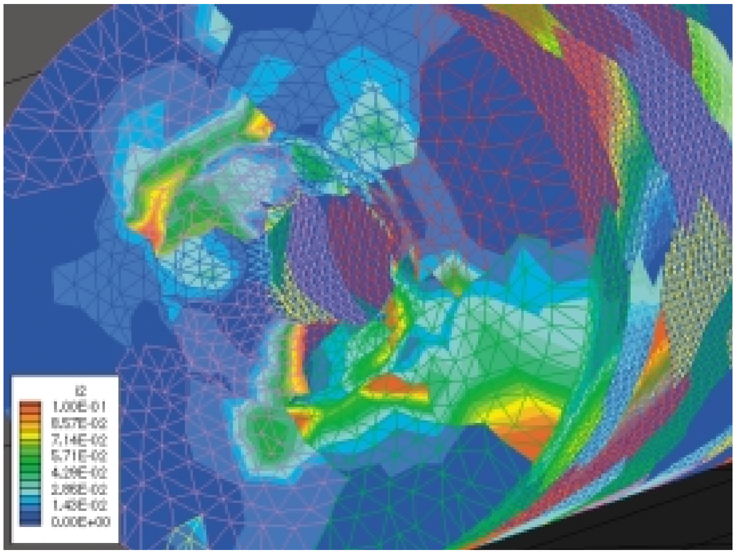
ASCI Defense Applications and Modeling Program

History and Background

The Advanced Simulation and Computing program (which retains its historical name ASCI) creates simulation capabilities through the development of advanced weapons codes and high-performance computing that incorporate high-fidelity scientific models validated against experimental results, past tests, and theory. The goal is to meet the science-based simulation requirements of the Stockpile Stewardship Program (SSP) so that the National Nuclear Security Administration (NNSA) can complete its nuclear weapons responsibilities. This includes the means to assess and certify the safety, performance, and reliability of nuclear weapons.

The ASCI program actively addresses stockpile issues by developing and using simulations to study problems ranging from advanced design and manufacturing processes, to understanding accident scenarios, to weapons aging and to the resolution of Significant Finding Investigations (SFI). This spectrum of scientific inquiry demands a balanced system of hardware, software, and computer science solutions.

The ASCI Defense Applications and Modeling Program develops and maintains all NNSA national laboratory weapons codes that support SSP research, including design and assessments, accident analysis, certification issues and manufacturing process studies. Development of the high-fidelity, full-systems codes requires new physics and materials models, improved algorithms, general code development, and a concerted effort in the verification of the codes and their validation against experimental data.



Dan Meiron provided the Integrated Simulation Capability Overview for the California Institute of Technology during a 2001 ASCI Site Review. He presented Caltech's parallel fracture capability and noted that additional work is underway to correctly model fracture across processor boundaries. Caltech's Virtual-Shock-Physics Test Facility (VTF) allows researchers to numerically simulate strong shock and detonation waves that collide with solid or fluid targets. Strong collaborations between the ASCI Alliance partners such as Caltech, and the national laboratories enhance computational science capabilities.

Advanced Applications Development

ASCI develops high-performance software applications for SSP simulation tools. Key to SSP objectives for initial implementation in 2004 and full implementation in 2010 is achieving milestones for critical applications codes in the intervening years. ASCI provides simulation tools and capabilities embodying the physical and chemical processes needed to predict the safety, reliability, performance, and manufacturability of weapon systems. The formidable challenge is to replace the empirical factors and adjustable parameters used in current calculations with predictive physical models.

This challenge demands large, complex computer codes, which drives the scale of computing hardware and infrastructure. Much of the increased computational capability must come from advances in the applications codes themselves. These applications will integrate three-dimensional capability, finer spatial resolution, and more accurate and robust physics. The development and implementation of improved numerical algorithms to address these new capabilities is a critical component of the applications strategies.

Verification and Validation (V&V)

Verification is the process of determining that computational software correctly represents a model of a physical process. The verification program evaluates current software engineering practices for application to the ASCI-scale simulations, and establishes requirements for software projects. The most essential goal of the verification portion of ASCI V&V is to ensure that the models from Advanced Applications yield analytically correct answers.

Validation is the process of determining the degree to which a computer model is an accurate representation of the real world, from the perspective of the intended model applications. Validation employs physical data and results from legacy codes.

SSP requires systematic, rigorous V&V to obtain the level of confidence expected of weapon simulations. Such V & V interfaces with many other stewardship elements and activities, requiring a great deal of coordination.

Materials and Physics Modeling (M&PM)

Historically, physical properties of materials significant to the nuclear weapons program were often inferred from integral test data. In the absence of new tests, there is a premium on the development of advanced capabilities—experimental, theoretical, and computational—to predict the physical properties of materials under conditions found in nuclear explosions and stockpile-to-target sequences.

Of particular interest are the physical properties of materials in regimes relevant to the performance, safety, and reliability of the nuclear stockpile — turbulence, instabilities and mix, spall, hydrodynamics, equations-of-state, and the dynamic properties of materials under conditions of high strain and high strain rates.

Physical processes involving turbulence, friction, and fracture take place at scales that are difficult to measure experimentally. A complete understanding requires knowledge of material properties and responses at vastly different length- and time-scales, as well as the linkage across these scales. Laboratory experiments conducted by the Defense Science Program, complemented by high-performance simulations using ASCI codes, provide the basis for predictive models and validated physical data of stockpile materials.

High-performance simulations linking quantum to continuum scales will lead to reliability predictions and lifetime assessment for corrosion, organic degradation, and thermal-mechanical fatigue of weapon electronic subsystems. Similarly, quantum-scale simulations and laser-driven shock compression experiments have validated the equation-of-state of hydrogen up to several megabars, providing valuable insight both into weapons performance and inertial confinement fusion.

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